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Congestion Management using Optimal Choice and Allocation of FACTS Controllers

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***Abstract*— This paper concerns the optimal choice and allocation of FACTS (Flexible AC Transmission Systems) devices in multi-machine power system using genetic algorithm. The objective is to improve the system loadability and the voltage stability. Using the proposed method, the locations of the FACTS devices, their types and rated values are optimized simultaneously. Different kinds of FACTS devices are simulated in this study: Thyristor Controlled Series Compensator (TCSC) and Static Var Compensator (SVC). The proposed algorithm is an effective and practical method for the choice and allocation of FACTS devices in large power systems.**

***Index Terms*—FACTS devices, TCSC, SVC, Genetic algorithm, restructured power systems.**

I. Introduction

Recently, countries of Western Europe started to open their electricity market. This deregulation, translated into a separation of generation and transmission, is taking place progressively. At the ultimate phase, every consumer will be able to buy his own electricity from any source desired (*Third Party Access*). Other countries such as Chile, UK, Norway and USA have already set off on the way to the liberalization. Each of them has its own marketing model [1], but in every case we note the same economical effects: i) a price decrease of the kilowatt-hour, particularly for large customers, and ii) a reduction of the disparities in regional costs.

On the technical side, we may observe an increase of the unplanned power exchanges due to the competition among utilities and to contracts concluded directly between producers and consumers. Problems could appear with the power flows, which obey Kirchhoff's laws. If the exchanges were not controlled, some lines located on particular paths may become overloaded, a phenomenon called *congestion* [2], and thus the full capacity of transmission interconnections could not be utilized. In the past, before opening the market, the control of power flows was in most part realized by reallocating productions. In a deregulated environment, this kind of control is not possible any more.

Appearance of FACTS devices (*Flexible AC Transmission Systems*) opens up new opportunities for controlling power and enhancing the usable capacity of existing transmission lines. Studies and realizations have shown their capabilities in steady-state or dynamic stability [3]-[5]. With their ability to change the apparent impedance of a transmission line, FACTS devices may be used for active power control, as well as reactive power or voltage control. For a meshed network, an optimal location of FACTS devices allows to control its power flows [6] and thus to increase the system loadability [7], [8]. However, a limit number of devices, beyond which this loadability cannot be improved, has been observed [9].

Among the above-quoted benefits, only some of them can be provided by a given kind of FACTS and it is important to choose the suitable type(s) of devices in order to reach a defined goal. In this project, we look for the optimal location of multi-type FACTS devices. Three different devices, with specific characteristics, have been selected and modeled for steady-state analysis. They are used in order to maximize the power transmitted by the network by controlling the power flows.

The objective of this project is to develop an algorithm to find the best locations for the FACTS devices, in order to maximize the system loadability while observing thermal and voltage constraints and minimizing losses. In other words, we look for increasing as much as possible the power transmitted by the network to the consumers, keeping the power system in a secure state in terms of branch loading and voltage levels.

Different kinds of FACTS devices and their different locations have varying advantages. In realizing the proposed objective, the suitable types of FACTS devices, their location and their ratings must be determined simultaneously. The optimal location of a given number of FACTS is a problem of combinatorial analysis. To solve such kind of problem, *heuristic* methods can be used. Among them, we have chosen the *genetic algorithms* (GAs) [10]. The algorithm is such that if one or more lines congested then, to select a suitable mathematical model of a TCSC, SVC and to get the optimal locations for TCSC, SVC using real parameter GA.

The basic idea about the FACTS devices have been well reported in Hingorani et.al [16], and Song et.al, [17], detailed explanation has been given for all the FACTS devices. H.Ambriz-Perez et.al, [18] has been presented SVC load flow models using total susceptance and firing angle methods. In [10] presented Genetic Algorithm to seek the optimal location of multi-type FACTS devices in power systems. In this, location, type and rated values of FACTS devices are optimized simultaneously. Locations of FACTS devices in power system are obtained on the basis of static and dynamic performance.

In [19] presented steady state security index for contingency analysis of the power system, which indicates the security of each contingency to determine the optimal

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location of SVC and UPFC. In [13-14] proposed the injection modeling of FACTS devices to find the sensitivity analysis to minimize line loss indices. [15] extended the work proposed in [13] to find injection model of UPFC and find system loss indices to optimally place the UPFC in the system. In [20] proposed GA based congestion management in deregulated power system using FACTS devices. In this line loading is taken as objective and social welfare is maximized while satisfying the operation and security related constraints. In [21] presented a method to determine the optimal location of TCSC has been suggested. The approach is based on the sensitivity of the reduction of total system reactive power loss and real power performance index.

Steady-state simulations are performed on IEEE 30 bus test power system. The results obtained are analyzed and commented. Using the proposed method, the locations of the FACTS devices, their types and rated values are optimized simultaneously. The proposed algorithm is an effective and practical method for the choice and allocation of FACTS devices in large power systems. Simulations are done on IEEE30 bus power systems for different types of FACTS devices. The results show that the simultaneous use of several kinds of controllers is the most efficient solution to increase the loadability, voltage stability and decrease the losses of the system. In all the cases (single- and multi-type FACTS devices), we observe a maximum number of devices beyond which this loadability, voltage stability cannot be improved.

II. Choice of Facts Devices

In an interconnected electrical network, power flows obey Kirchhoff's laws. Usually, the value of the transverse conductance is close to zero and for most transmission lines, the resistance is small compared to the reactance. By neglecting the transverse capacitance, active and reactive power transmitted by a line between two buses 1 and 2 may be approximated by the following relationships:

$$P_{12}=V_1V_2/X_{12}\mathrm{Sin}\theta_{12} \qquad (1)$$

$$Q_{12}=1/X_{12}(V_1^2-V_1V_2\mathrm{Cos}\theta_{12}) \qquad (2)$$

where V_1 and V_2 voltages at buses 1 and 2, X_{12} is reactance of the line, θ_{12} is angle between $\underline{V}_1$ and $\underline{V}_2$ (underlined variable denotes a phasor).

Under normal operating conditions for high voltage lines $V_1 = V_2$ and θ_{12} is typically small. In that case there is a decoupling between the control of the flows of active versus reactive power. Active power flow is coupled with θ_{12} and reactive power flow is linked to the difference (V_1-V_2). The control of the value of X_{12} acts on both and modify active and reactive power.

Two different types of devices have been chosen to be optimally located in order to control power flows. Each of them is able to change only one of the above-mentioned parameters. The first one is the TCSC (*Thyristor Controlled Series Capacitor*), which permits to modify the reactance of the line X_{12}. The SVC (*Static Var Compensator*) is used to absorb or inject reactive power at the bus.

The models of the FACTS devices are developed to be suitable for steady-state. Each device may take a fixed number of discrete values. The TCSC may have one of the two possible characteristics: capacitive or inductive, respectively to decrease or increase the reactance of the line X_L. It is modeled with three ideal switched elements in parallel: a capacitance, an inductance and a simple wire, which permits the TCSC to have the value zero. The capacitance and the inductance are variable and their values are function of the reactance of the line in which the device is located.

In order to avoid resonance, only one of the three elements can be switched at a time. Moreover, to not overcompensate the line, the maximum value of the capacitance is fixed at -$0.8X_L$. For the inductance, the maximum is $0.2\ X_L$

The SVC may have two characters: inductive or capacitive. In the first case it absorbs reactive power while in the second one the reactive power is injected. The SVC is modelled with two ideal switched elements in parallel: a capacitance and an inductance. It may take values characterized by the reactive power injected or absorbed at the voltage of 1 p.u. The values are between -100 MVar and 100 MVar.

III. Solution Methodology

Heuristic methods may be used to solve combinatorial optimization problems. These methods are called "intelligent," because the move from one solution to another is done using rules close to the human reasoning. The heuristic algorithms search for a solution inside a subspace of the total search space. Thus, they are able to give a good solution of a certain problem in a reasonable computation time, but they do not assure to reach the global optimum. The most important advantage of heuristic methods lies in the fact that they are not limited by restrictive assumptions about the search space like continuity, existence of derivative of objective function, etc.

Several heuristic methods exist. Among them, we may quote Tabu Search method (TS), Simulated Annealing (SA), and Genetic Algorithms (GAs). Each one has its own properties and drawbacks. The TS is basically a deterministic method, and experience shows that no random process might restrict the search in the set of solutions. The SA needs long computation time. Further, there are an important number of parameters that are difficult to determine, such as the *cooling schedule*.

In this paper, genetic algorithms (GAs) are used. Genetic algorithms are based on the mechanisms of natural selection. They always produce high quality solutions because they are independent of the choice of the initial configurations. Moreover, they are computationally simple and easy to implement. One of the drawbacks is their possibility to converge prematurely to a suboptimal solution.

The optimal solution is sought after from a population of solutions using random process. A new generation is created by applying to the current population the three following

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operators: *reproduction*, *crossover* and *mutation*. The reproduction is a process dependant of an objective function to maximize or minimize according to the cases.

A. Description of the Used Genetic Algorithm:

Based on the mechanisms of natural selection and genetics, GAs (genetic algorithms) are global search techniques. The GAs start with random generation of initial population and then the selection, crossover and mutation are preceded until the best population is found. Particularly, GAs are practical algorithm and easy to be implemented in the power system analysis.

The goal of the optimization is to find the best location of a given number of FACTS devices in accordance with a defined criterion. A configuration of n_F FACTS devices is defined with three parameters: the location of the devices, their types and their values. In order to take into account the three aforementioned parameters in the optimization, a particular coding is developed. An individual is represented with three strings of length n_F, where n_F is the number of devices to locate optimally.

1) Encoding:

The objective is to find the optimal locations for the FACTS devices within the equality and inequality constrains. Therefore, the configuration of FACTS devices is encoded by three parameters: the location, type and its rated value. Each individual is represented by N_{FACTS} number of strings, where N_{FACTS} is the number of FACTS devices needed to be analyzed in the power system, as shown in Fig. 2.

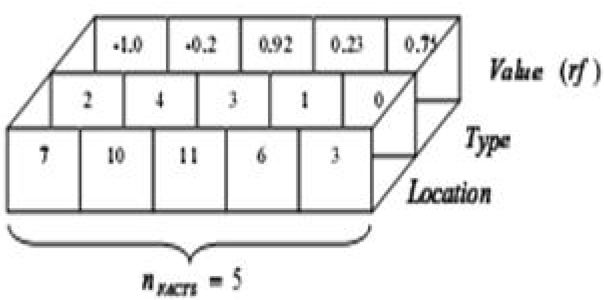

Fig. 2. Individual configuration of FACTS devices

The first string corresponds to the location of the devices. It contains the numbers of the lines where the FACTS are to be located. Each line could appear at maximum once in the string. The order of the lines in the string is not important for a given configuration, but could have its importance when applying the operator of crossover. Note that the number of the line is related with the order of the branches in the description file of the power system.

The second string is related to the types of the devices. A value is assigned to each type of modeled FACTS device: 1 for SVC; 2 for TCSC and 3 for no FACTS device. By this way new other types of FACTS may be easily added.

The last value *rf* represents the rating of each FACTS device. This value varies continuously between –1 and +1. –1 corresponding to the minimum value that the device can take and 1 to the maximum. The real value of each FACTS device is then converted according to the different FACTS model under the following criterion:

2) TCSC:

By modifying the reactance of the transmission line, the TCSC acts as the capacitive or inductive compensation respectively. In this study, the reactance of the transmission line is adjusted by TCSC directly. The rating of TCSC is depend on the reactance of the transmission line where the TCSC is located:

$$X_{ij}=X_{Line}+X_{TCSC}\ ,\ X_{TCSC}=rtcsc*X_{Line} \qquad (3)$$

where X_{Line} is the reactance of the transmission line where the TCSC to be installed and *rtcsc* is the coefficient which represents the degree of compensation by TCSC. TCSC has a working range between $-0.7X_{Line}$ and $0.2X_{Line}$. Therefore *rf* is converted into the real degree of compensation *rtcsc* using the following equation:

$$rtcsc = rf*0.45-0.25 \qquad (4)$$

3) SVC:

The SVC can be operated as both inductive and capacitive compensation. It is modeled as an ideal reactive power injection at bus i:

$$\Delta Q = Q_{SVC} \qquad (5)$$

To obtain the entire initial population, these operations are repeated n_{ind} times. where n_{facts} is number of FACTS devices to be located, n_{type} is FACTS types, $n_{location}$ is possible locations for FACTS devices and n_{ind} = number of individuals of population

B. Objectives of the Optimization:

The goal of the optimization is to perform a best utilization of the existing transmission lines. In this respect, the FACTS devices are located in order to maximize the system loadability while observing thermal and voltage constraints. Loss minimization is taken as another objective.

The objective function is built in order to penalize the configurations of FACTS leading to overloaded transmission lines and over or under voltages at buses. Only the technical benefits of the FACTS controllers, in terms of loadability, are taken into account. Other criteria such as costs of installing and maintaining devices are not taken into consideration at this stage.

1) Case i) Branch Loading (BL) is taken as objective:

The objective function concerns branch loading and penalizes overloads in the lines. This term, called *ovl*, is computed for every line of the network. While the branch loading is less than 100%, its value is equal to 1; then it decreases exponentially with the overload. To accelerate the convergence, the product of all objective function is taken.

$$J_1 = \prod_{LINE} OVL_{LINE} \qquad (6)$$

$$OVL = \begin{cases} 1 & ;if\ P_{pq} \le P_{pq}^{\max} \\ \exp(\lambda\,|1 - P_{pq}/P_{pq}^{\max}|);if\ P_{pq} > P_{pq}^{\max} \end{cases}$$

Where, OVL is line overload factor.

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2) Case ii) Voltage Levels (VL) are taken as objective:

This objective function concerns voltage levels. It favours buses voltages close to 1 p.u. The function is calculated for all buses of the power system. For voltage levels comprised between 0.95 p.u. and 1.05 p.u., the value of the objective function *Vtg* is equal to 1. Outside this range, the value decreases exponentially with the voltage deviation.

$$J_2 = \prod_{BUS} VS_{BUS} \qquad (7)$$

$$VS = \begin{cases} 1 & : if\ 0.9 \le V_b \le 1.1 \\ \exp(\mu \mid 1 - V_b \mid); & otherwise \end{cases}$$

where P_{pq} is Real power flow, P_{pq}^{max} is Therma limit for the line between buses p and q.

3) Case iii) Loss Minimization is taken as objective:

For reactive power optimization, system transmission loss minimization is considered as the objective function.

$$f = \sum_{i=1}^{Nl} Loss_i \qquad (8)$$

where Nl is the number of transmission lines in a power system.

C. Proposed Algorithm:

1 Read the system data.
   a. Data required for GA.
   (population size N, string length, P_e, P_c, P_m , number of generators, generator voltage magnitudes, cost coefficients, maximum and minimum power output of generators, Voltage limits of buses, line flow limit, and itermax)
   b. Data required for load flow solution. (n, Nl, nslack, max iterations, epsilon, linedata, bus data, shunts)
2 Form Ybus using sparsity technique.
3 Form [B'] constant slope matrix and decompose using cholesky decomposition.
4 Randomly generate the current population members containing location, type and rated values of FACTS controllers.
5 Set iteration count =1
6 Set chromosome count, k =1
7 Modify the elements of Ybus depending on positions and rated values of TCSC and SVC.
8. Run FDC load flow.
9. From converged load flow solution compute slack bus power, fuel cost, line losses, bus voltage magnitudes, phase angles, Spq, line loading.
10. Check for limits on load bus voltage magnitudes, generator reactive power limits, slack bus power limit, and line flow limit.
11. Calculate penalty factors for violated functional constraints.
12. Compute the objective function.
13. Calculate fitness of the chromosome considering objective function.
14. Check if k < current population size. if yes, increment chromosome count, k = k+1, and go to step 7.
15. Sort current population members based on fitness value.
16. Copy the best fitness solutions by elitism operation.
17. Apply tournament selection, uniform crossover, GA operators and mutation to remaining population members.
18. Demodify the Ybus after every iteration.
19. Increment iteration count. If (iter < itermax) goto step 5 else problem is not converged in itermax iterations. STOP.
20. If fitness of all chromosomes are equal then run the program by changing GA parameters.
21. Calculate the objective function values,percentage power flow through lines,voltage magnitudes and phase angles.

IV. Results and Discussion

The test system considered is IEEE 30-bus, 41-branch system. The network parameters of the system are taken from [5]. Real parameter Genetic Algorithms are used to determine the optimal location of FACTS controllers. GA parameters: Population size: 40, maximum number of generations: 200, Blended (BLX-α) Crossover Probability: 0.95, mutation

Probability: 0.001 and elitism index: 0.15. Tournament parent selection technique is used. The algorithm is stopped when all chromosomes assume similar fitness values.

The study considers the following three cases.

Case-i is optimal location of FACTS controllers considering Branch loading (BL) as objective function with uniform loading of 130%, line outage and by increasing the transaction.

Case-ii is optimal location of FACTS controllers considering Voltage stability (VS) as objective function with uniform loading of 130% and line outage.

Case-iii is optimal location of FACTS controllers considering Loss minimization (LM) as objective function with uniform loading of 130% and line outage.

Comparison of results obtained for different cases using Genetic algorithms along with base case solution is summarized. The 'Base case' refers to the load flow solution without any optimization objective [24].

Table 1 shows the comparison of objective function values for Base case and 130% of uniform loading and after including the FACTS devices considering Branching loading, Voltage stability and Loss minimization as objective functions. Base case refers to the system normal operating condition, without any optimization objective.

When BL objective is optimized, the obtained BL is 2837.1096, and VS, loss are 1329.8389, 0.210257p.u respectively. When VS objective is optimized, the obtained VS is 1389.583, but BL decreased to 2289.215 and loss changed to 0.193001p.u.

Table 2 shows the lines which are overloaded when uniform loading of 130% is applied. When the system is uniformly overloaded by 130% then lines 1 and 10 are overloaded. This overloading can be relieved by placing SVC at 25th bus with Bsvc of -0.005275 and TCSC in 40th line with

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TABLE I. COMPARISON OF OBJECTIVE FUNCTION VALUES FOR BASE CASE AND 130% LOADING WITH FACTS DEVICES

Objective Function	Base case	130% loading with FACTS devices		
		BL objective	VS objective	LM objective
Branch Loading(BL)	2537.045	**2837.1096**	2289.215	2145.3538
Voltage Stability(VS)	1210.617	1329.8389	**1389.583**	1023.693
Loss Minimization(LM)	0.190028	0.210257	0.193001	**0.179913**

TABLE II LINES TO BE OVERLOADED FOR UNIFORM LOADING OF 130% BEFORE AND AFTER PLACING THE FACTS CONTROLLERS CONSIDERING BRANCH LOADING (BL) AS OBJECTIVE FUNCTION

Line No.	From Bus	To Bus	Spq in Base case	Spq in 130% loading	Spq after including FACTS devices	Spq max Through lines	Line loading in Base case	Line loading with 130% loading	Line loading after including FACTS devices
1	**1**	**2**	**1.0944**	**1.6385**	**1.2356**	**1.3000**	**84.1830**	**126.036**	**95.0462**
10	**6**	**8**	**0.1638**	**0.3551**	**0.3132**	**0.3200**	**51.1727**	**110.970**	**97.8750**

TABLE III. OPTIMAL LOCATION, TYPE AND RATED VALUES OF FACTS DEVICES FOR UNIFORM LOADING OF 130%

Rated Value of FACTS device	-0.005275	-0.118683	-0.219839
Type of FACTS device	1	2	0
Location of FACTS device	25	40	27

X_{TCSC} of -0.118683.

Table 3 Voltage magnitudes and Phase angles of IEEE30 bus system in base case, uniform loading of 130% and after placing the FACTS controllers considering Branch loading (BL) as objective function.

Table 4 shows the comparison of objective function values for line 5 given outage and after including the FACTS devices considering Branching loading, Voltage stability and Loss minimization as objective functions.

TABLE IV. COMPARISON OF OBJECTIVE FUNCTION VALUES WHEN LINE 5 GIVEN OUTAGE WITH AND WITHOUT FACTS DEVICES

Objective Function	Line 5 is given outage	Line 5 is given outage with FACTS devices		
		BL objective	VS objective	LM objective
Branch Loading(BL)	25.0162	**488.06224**	486.1121	483.3938
Voltage Stability(VS)	121.1703	242.7302	**314.5073**	248.7432
Loss Minimization(LM)	0.1691	0.17025	0.17058	**0.167679**

Table 5 shows the comparison of objective function values for line 36 given outage and after including the FACTS devices considering Branching loading, Voltage stability and Loss minimization as objective functions.

TABLE V. COMPARISON OF OBJECTIVE FUNCTION VALUES WHEN LINE 36 GIVEN OUTAGE WITH AND WITHOUT FACTS DEVICES

Objective Function	Line 36 is given outage	Line 36 is given outage with FACTS devices		
		BL objective	VS objective	LM objective
Branch Loading(BL)	60.8893	**621.8524**	601.7279	612.9847
Voltage Stability(VS)	183.7809	302.0251	**309.2734**	295.9104
Loss Minimization(LM)	0.12553	0.128988	0.127814	**0.12386**

TABLE VI. LOCATION, TYPE AND RATED VALUES OF FACTS DEVICES FOR LINE 5 OUTAGE

Rated Value of FACTS device	-0.375057	-0.080656	-0.008245	-0.024216
Type of FACTS device	1	2	2	2
Location of FACTS device	11	14	23	11

TABLE VII. OPTIMAL LOCATION, TYPE AND RATED VALUES OF FACTS DEVICES FOR LINE 36 OUTAGE

Rated Value of FACTS device	-0.325978	-0.346388	0.244239	0	0
Type of FACTS device	2	2	1	0	0
Location of FACTS device	33	31	28	10	29

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TABLE VIII. LOCATION, TYPE AND RATED VALUES OF FACTS DEVICES FOR BILATERAL TRANSACTION BETWEEN NODE 13 AND NODE 5

Rated Value of FACTS device	0	0.335992	-0.037881
Type of FACTS device	0	2	1
Location of FACTS device	12	34	13

TABLE IX. LOCATION, TYPE AND RATED VALUES OF FACTS DEVICES FOR BILATERAL TRANSACTION BETWEEN NODE 11 AND NODE 5

Rated Value of FACTS device	-0.000638	-0.030751	0	0
Type of FACTS device	2	2	0	0
Location of FACTS device	34	29	23	13

A. Bilateral Transaction

If a transaction is performed between single source and single sink then transaction is called bilateral transaction. Consider a bilateral transaction between the supplier at node 13 and the consumer at node 5.At base case P_{gen} at supplier node 13 is 0.1691 p.u.and P_{load} at consumer node is 0.942 p.u.By increasing the transaction amount by 145% then line 1 gets loaded by 102.1176%. This overloading can be relieved by placing SVC at bus 13 with B_{SVC} of -0.037881 and TCSC in line no.24 with X_{TCSC} of 0.335992.

Consider another bilateral transaction is performed between the supplier at node 11 and the consumer at node 5.At base case P_{gen} at supplier node 11 is 0.1793 and P_{load} at consumer node is 0.942.By increasing the transaction by 200% then line 1 gets loaded by 127.5095%. This can be relieved by placing two TCSC devices in lines 29 and 34 with X_{TCSC} of -0.030751 and -0.000638 respectively.

By increasing the transaction by 220% between the supplier at node 11 and the consumer at node 5 then line 1 and line 8 gets loaded by 137.8715% and 106.1109%. This can be relieved by placing SVC at bus 5 with B_{SVC} of -0.547196 and three TCSC devices in lines 4, 25 and 32 with X_{TCSC} of -0.009161,-0.33476 and -0.665461 respectively.

TABLE X.. LOCATION, TYPE AND RATED VALUES OF FACTS DEVICES BY INCREASING THE TRANSACTION TO 220% BETWEEN NODE 11 AND 5

Rated Value of FACTS device	-0.5472	-0.0092	-0.6655	-0.3347
Type of FACTS device	1	2	2	2
Location of FACTS device	5	4	32	25

B. Multilateral Transaction

If a transaction is performed between more than one source and one sink then that transaction is called multilateral transaction. Consider a multilateral transaction between the supplier at node 2 and the consumer at nodes 8 and 21 .At base case P_{gen} at supplier node 13 is 0.5756 p.u., P_{load} at consumer nodes 8 and 21 are 0.3 p.u, 0.175p.u respectively. By increasing the transaction amount by 170% at supplier node and drawing the same amount at consumer nodes then lines 10 and 27 gets loaded by 102.2923% and 116.2234% respectively. This overloading can be relieved by placing two SVCs at buses 3 and 30 with B_{SVC} of -0.474376,-0.302777respectively and TCSC in line no.16 with X_{TCSC} of -0.028801.

TABLE XI. LOCATION, TYPE AND RATED VALUES OF FACTS DEVICES FOR MULTILATERAL TRANSACTION BETWEEN SUPPLIER NODE 2 AND CONSUMER NODES 8 AND 21

Rated Value of FACTS device	-0.3028	-0.4744	0	-0.0288
Type of FACTS device	1	1	0	2
Location of FACTS device	30	3	11	16

From the above studies, it is observed that congestion is relieved by optimally placing the FACTS devices (SVC and TCSC) when the congestion is created by uniformly loading the lines or one of the line is given outage or by increasing the transaction amount between the supplier node and the consumer node. The objectives of this optimization are branch loading maximization, voltage stability maximization and loss minimization. Considering branch loading as single objective optimization then the objective function values obtained for voltage stability and loss minimization are not optimum. Therefore, these optimization problems should not be treated as independent objectives. The optimal location of FACTS controllers problem with these conflicting objectives should be treated using multi-objective optimization algorithms. Suitable and effective algorithm may be derived for multi-objective optimization problem. The work in this direction is reported in next chapter.

V. CONCLUSION

An algorithm for congestion management using optimal location of FACTS controllers has been proposed. The proposed model uses the real parameter genetic algorithm to find optimal location. The optimal location of FACTS controllers problem, with system branch loading maximization or loss minimization or voltage stability maximization as objective function. Reactive power generations of generators, load bus voltage magnitudes, slack bus active generation and line flow limits are considered as functional operating constraints. Genetic algorithms are used as optimization tool for solving the optimal location of FACTS controllers problem. IEEE 30 bus system is considered to study various cases. Three different cases have been examined for optimal location of FACTS controllers problem.

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